A Review of the Physiological Effects and Mechanisms of Singing

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Summary: Daily experience suggests that singing can energize us and even provide a physical workout. A growing amount of evidence has been presented to support anecdotal claims of the benefits of singing on health and well-being. Singing has been shown to be related to numerous physiological changes. The cardiorespiratory system is utilized during persistent singing training, resulting in enhanced respiratory muscles and an optimized breathing mode. In addition, singing can also cause changes in neurotransmitters and hormones, including the upregulation of oxytocin, immunoglobulin A, and endorphins, which improves immune function and increases feelings of happiness. This review is organized by respiratory, circulatory, and hormonal changes that are collectively a part of singing in a healthy population. The various studies are discussed with the intention of helping researchers and clinicians realize the potential benefit of singing and provide a clinical option as an adjunct therapy for a given situation. Better understanding of physiological mechanisms will lay a solid theoretical foundation for singing activities and will present important implications for further study. Evaluations of existing research and recommendations for future research are given to promote the scale and duration to better demonstrate the effectiveness of singing before it can be recommended in clinical guidelines and satisfy criteria for funding by commissioners of health and social care.

Key Words: Singing–Health–Mechanism–Physiological effects–Hormones.

INTRODUCTION

Singing is the act of producing musical sounds with the voice, an activity whose origins are lost in antiquity.[1] In modern times, singing is a universal activity, pervading the daily lives of individuals from diverse cultural, demographic, and political backgrounds. There are diverse forms of singing, such as everyday singing, group singing, karaoke singing, solo singing, and singing education. There is also a large variety of singing styles such as rock, gospel, country, musical theater, and close-knit a cappella.[2] Group singing can be found in a wide range of settings including hospitals, workplaces, local communities, homeless shelters, and prisons as well as more traditional venues such as churches and concert halls.[3,4] In addition, karaoke singing is one of the most popular extracurricular activities among Asian youth, especially in China and Japan.[5]

Although singing is generally considered to be a form of entertainment rather than exercise, it has also been related to numerous health and well-being outcomes. As early as 1930, Rollrath found that many famous singers had lived to be 80 or even more than 100 years old, which suggested that singing could increase longevity.[6] Recent years have witnessed an incremental recognition of the value of singing activities in improving mental and physical health in both nonclinical and clinical settings.[7] Singing, the active music intervention, has been found to bring about better outcomes than the receptive music intervention (eg, listening or music games) as an adjunctive treatment option.[8] Studies have realized the effects of singing on lung diseases, especially chronic obstructive pulmonary disease[9] and asthma,[10] as well as other chronic medical conditions, including Parkinson's disease[11] and quadriplegia,[12] due to increased lung vital capacity (LVC) and enhanced respiratory muscles. Furthermore, singing has also demonstrated positive impacts on emotional states and neural network reconfiguration, so that the symptoms of mood disorders,[13] dementia,[14–16] and aphasia[17] improve after singing intervention. On the other hand, less research has been conducted on the healthy population or the neuroendocrine system as a potential underlying mechanism.[18–20]

Given the growing popularity of singing, more value should be placed on scientific research highlighting its benefits and mechanisms. Therapeutic benefits of singing may be better understood with a greater knowledge of the mechanisms underlying the relationship between singing and health in humans.[21] Nowadays, many studies related to singing focus on the feasibility and practicality of singing as an adjunct therapy to patients rather than as a rewarding exercise with regard to general well-being. To our knowledge, no review has been done that summarizes the data collected on the biological and neurochemical benefits of singing. The purpose of this manuscript is twofold: We discuss changes in respiratory, circulatory, and endocrine systems during all singing tasks and characterize these relationships by determining the extent to which neurochemistry results in these changes. The second part of this manuscript is concerned with singing therapy and related factors, indicating some implications and limitations of existing research.

RESPIRATORY CHANGES

Respiratory changes are one of the most obvious and perceptible changes associated with singing. The air that is exhaled from the lungs is the source of power for articulation and singing. Continuously stable air pressure vibrates the vocal cords, while resonance apparatuses and articulators adjust the structures to produce different timbres.[22] In the process of singing, repeated utilization of the corresponding organs and the surrounding

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structures can not only coordinate the subsystems but also exercise the respiratory muscles, leading to improved lung function.[23] Professional singers with correct and proper singing patterns can be seen to have an improved "breathing reserve"; that is, they adjust their breathing mode in order to transfer kinetic energy into sound energy more efficiently. This creates a better tolerance to the effects of vocal pathologies.[24]

Gould and Okamura[25] found no significant difference in total lung capacity (TLC) between professional singers, vocal music students, and untrained persons, while the ratio of the residual lung volume to total lung capacity (RV/TLC) of professional singers was significantly lower than that of the other two groups, and the RV/TLC values of the vocal music students were also lower than those of the untrained group. The results suggest that singing can help healthy people take full advantage of the same amount of lung function, indicating better breathing efficiency, which increased with the singing training time. Carroll et al[26] compared the forced expiratory volume in 1 second (FEV1), forced vital capacity (FVC), and forced expiratory flow of 40 professional singers with the standard values of a healthy population. The average results of professional singers were greater than standard values. Irzaldy et al[27] conducted lung measurements in 10 chorus members and 10 ordinary students. Significant differences were found in LVC and FVC ($P = 0.02$, $P = 0.01$, respectively), while no significant difference was found in inspiratory volume, suggesting that the promotion of the relevant indicators was closely related to the expiratory phase. Ksinopoulou et al[28] conducted a randomized controlled trial, in which 58 professional singers and 22 wind-instrument players were enrolled in the experimental group (45 males and 35 females) and 80 healthy subjects were recruited as control groups. There were significant differences in FVC, FEV1, and peak expiratory flow rate (PEFR) between the two groups ($P < 0.01$, $P < 0.01$, $P = 0.001$, respectively), while a significant difference in the FEV1/FVC ratio was only found among the female participants ($P = 0.001$). Nevertheless, Schorr-Lesnick et al[29] compared 34 singers and 48 wind-instrument players with a control group of 31 string or percussion performers. There was no significant difference between the two groups in FVC, mean forced expiratory flow, FEV1/FVC value, maximum expiratory pressure, or maximum inspiratory pressure. This remained true when tested independently and when corrected for age, gender, weight, height, and smoking.

CIRCULATORY CHANGES

Along with the respiratory changes, the circulatory system may change depending on respiratory sinus arrhythmia (RSA). RSA is a special physiological phenomenon where exhalation can increase the vagus nerve (parasympathetic nerve) tension, which results in the extended sinus P-P cycle and vice versa.[30,31] RSA can effectively accelerate lung gas exchange by matching alveolar ventilation and capillary perfusion, and save the energy of the cardiorespiratory system by suppressing unnecessary heartbeat and ineffective ventilation during exhalation.[32,33] Grape et al[34] considered that singing can repeatedly train synergies between the respiratory system and the circulatory system to achieve the best match and show a better breathing cycle vigor. Thus, RSA may be the reason why singing further induces heart rate variability (HRV), the variability between the R-R intervals in successive heartbeats.[35] A reduced HRV is not only an independent risk factor for sudden cardiac death and arrhythmia events but is also related to psychiatric disorders such as depression and anxiety.[36,37] The HRV of 15 students was measured after the performances of different types of singing (humming, mantras, hymns).[38] The results suggest that singing increases HRV, and when the music structure is regular, HRV profiles tend to conform in terms of frequency and phase. Grape et al[34] found that professional singers experienced more significant HRV changes than amateurs during singing.

On the other hand, Niu et al[39] reported the case of a 76-year-old woman with chronic stable hypertension who experienced severely elevated blood pressure prior to total knee replacement surgery and was unresponsive to antihypertensive drugs (systolic blood pressure continued to fluctuate around 200 mmHg). In this case, her blood pressure was found to have dramatically dropped below 180 mmHg systolic after she sang several religious songs. Blood pressure measurements were conducted in 91 instrumentalists and 51 professional singers by Eller et al.[40] It was found that the average blood pressure of the professional singers was significantly lower than that of the instrument players. Valentine and Evans[41] presented that decreased blood systolic pressure and increased diastolic blood pressure were found after respective group activities in all singing groups (10 music majors and 13 amateur choirs), and changes in the two singing conditions were not significantly different from each other. Two groups of singers (n = 12, 13) and a group of nonsingers (n = 12) each produced the national anthem by speaking, by singing the words, and by humming the melody in a study by Formby et al.[42] No significant difference was found in the cerebral blood flow between these groups during speaking or singing.

CHANGES IN NEUROPEPTIDES AND HORMONES

In addition to changes in the cardiovascular system, singing has been shown to help people ease anxiety, bring euphoria, and create a sense of belonging. For example, a study of 210 adults was conducted over an 18-month period, in which 108 members were recruited into the singing group to participate in community singing rehearsals, while the remaining members were recruited as the control group.[43] Results revealed a significant reduction in the proportion of adults in the singing group classified as depressed and a concomitant significant increase in resilience levels, quality of life, sense of connectedness, and social support among this group. There were no significant changes for these variables in the comparison group. Many scholars have noticed this phenomenon and have tried to explore the mechanism behind the neural chemistry, but some studies have had opposite variation tendencies in these neuropeptides and hormones.

Adrenocorticotropic hormones (ACTHs) and glucocorticoids are both important components of the hypothalamic–pituitary–adrenal axis (HPA axis), and are essential hormones to keeping an individual excited and aroused. Increased HPA activity in response to stressful situations is part of the natural fight-or-flight response and leads to an inhibited immune response, narrowed arteries, and increased epinephrine, resulting in raised blood pressure.[44] Fancourt et al[45] examined the impact of singing in a low-stress performance situation (rehearsal without an